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edited by A. V. G. Betts, and F. Kidd

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The evolution of ceramic manufacturing technology during the Late Neolithic and Transitional Chalcolithic periods at Tepe Pardis, Iran

By Hassan Fazeli Nashali, Massimo Vidale, Pierluigi Bianchetti, Giuseppe Guida, Robin Coningham

Keywords: Iran, Neolithic, Chalcolithic, Ceramic, Kiln, Wheel throwing, Tepe Pardis, Technology, Cheshmeh-Ali Pottery, Sialk I ceramic

کلید واژه: ایران، نوسنگی، مس-سنگ، سفال، کوره، چرخ سفالگری، تپة پردیس، تکنولوژی، سفال نوع چشمه علی، سیلک I

Introduction

In 2003 an international project was launched in order to study the socio-economic transformation of the Neolithic and the Chalcolithic settlements within the Tehran plain, Iran.[1] One of the main objectives was to study the evolution of craft specialization and settlement patterns of pre-urban societies within the Tehran plain. The research methodology consists of multidisciplinary work including excavations at Tepe Pardis, a settlement survey, geoarchaeological studies and reconstruction of subsistence strategies of the local prehistoric societies. The main objectives of Tepe Pardis excavation were to access new C14 samples and to complete the chronological sequences of the Tehran plain prehistory. We also searched for direct evidence of ceramic workshops during the Transitional Chalcolithic period. The prehistoric layers of the site cover more than 2000 years of occupation, from the Late Neolithic to the Late Chalcolithic period. Unfortunately, during the later periods, and also because of modern activities, a great part of the site (in particular the fourth millennium contexts) was destroyed. At present, the best preserved layers of the site cover the Transitional Chalcolithic period and also two meters of the Late Neolithic stratigraphy. The main results of two years of horizontal excavations at Tepe Pardis are outlined in the following.

During the Transitional Chalcolithic period (5200–4600 BC) the site was used for ceramic production. It seems the residential part (the domestic space) was separated from the workshops area. From about 5200 to 4600 the whole area (400 m^2) was constantly used for making vessels. All layers contain kiln remains and other artifacts related to ceramic manufacturing. This would imply a long term of permanent ceramic production from the end of sixth and the first half of fifth millennium BC.

During the two years of excavation at the site, the team has not only recorded what remains of kiln structures and ceramic manufacturing dumps but also a possible example of a "slow wheel" and other artifacts related to ceramic production.

We also found an irrigation channel system dating back to 5250 BC.[2]

The Transitional Chalcolithic societies of the central plateau of Iran witnessed agricultural intensification and a growth of complexity in terms of social ranking, reflected in mortuary practices and ritual activities; long distance trade and growing specialization in craft production were also at play.[3] However, one of the important differences between the Late Neolithic and the Chalcolithic periods involves cultural materials, and more precisely a noticeable change in ceramic style. The colour of the Late Neolithic Buff Ware – very pale brown – changed during the Transitional Chalcolithic period to a very fine black on red type. Such a stylistic change affected not only the surface colour but also decoration and manufacturing technology in general. During the Late Neolithic period the interior surface of the open vessels was painted with geometric designs and the exterior was covered with simple narrow bands. In contrast, since ca. 5200 BC, black-on-red, very fine decorated ceramics were painted on the exterior with a complex repertory of geometric, vegetal and animal motifs. The selection of standardized materials and careful burnishing of the surfaces are other noticeable aspects of the Transitional Chalcolithic period.[4] In order to study the changing techniques and the organization of ceramic production from the Neolithic to the Transitional Chalcolithic period, the following relevant questions may be posed.

What caused the general chromatic change of the pottery from the Late Neolithic to the Chalcolithic period? Was this change due the selection of

1 Coningham et al. 2004; Fazeli et al. 2007.

2 Gillmore et al. 2009.
3 Fazeli 2001; Fazeli/Abbasnezhad 2005.
4 Fazeli 2001.

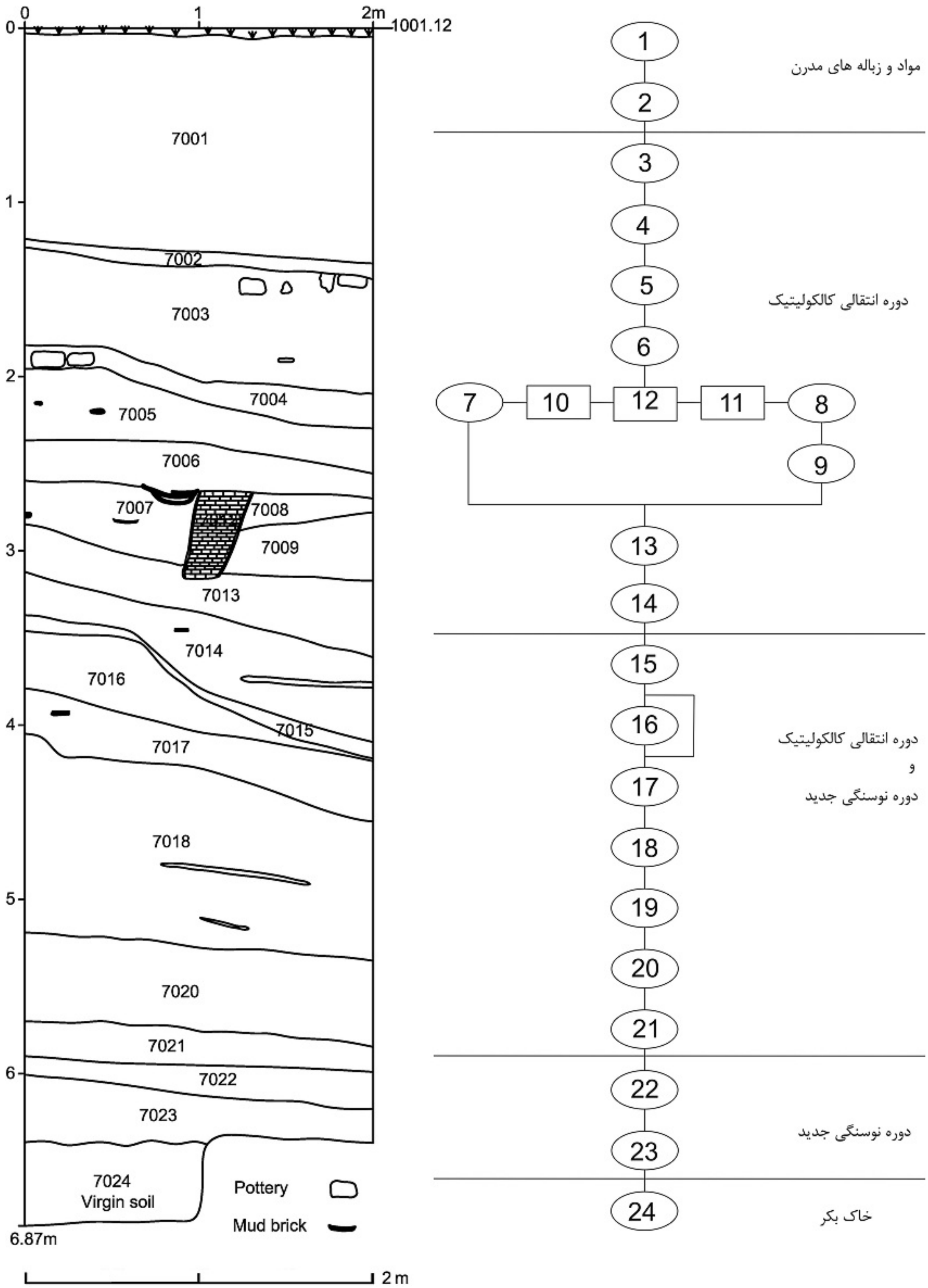


Fig. 1
Tepe Pardis. Stratigraphy of test trench TP07-VII. Late Neolithic (layers 7023-7022), Transitional Chalcolithic (layers 7021 to 7004)

layer	Coarse Chaff-Tempered Unpainted	Late Neolithic Buff Painted	Chalcolithic Black-on-Red Painted	Very Fine Painted	Chalcolithic Unpainted	Other Classes
7004	9	–	47	–	13	2**
7005	2	–	30	5	29	
7006	20	–	29	–	20	
7007	73	–	11	–	4	
7009	–	–	3	–	1	
7013	4	–	72	11	81	2 BW, 1 BM
7014	–	–	14	5	16	1 BW
7015	6	–	43	2	50	1 BB
7017	23	3	37	–	52	
7018	25	12	87	8	215	8 BB, 1*
7020	4	13	48	2	87	1 BB, 1 BW
7021	9	13	46	1	81	2 BB, 1*
7022	10	3	–	–		–
7023	17	9	–	–		–

Tab. 1
Tepe Pardis, Tr. VII-TP07. Tabulation of main ceramic classes and other finds. Total: 1236 counted potsherds. BB = Black Burnished ware; BW: Buff unslipped Ware; BM = Basket Marked ware, possibly vessels built with slabs applied onto a canister.
The sign 1* marks the stratigraphic setting of the 4 potsherds identified in the sequence as made on a fast potter's wheel (see text)

new raw materials, or did it result from a precise technological choice in terms of firing techniques?

When was the potter's wheel first introduced in the central plateau of Iran? This innovation is extremely relevant for the study of large scale ceramic production and its standardization. In 2006 the team found in Trench IV a possible "slow wheel" or tournette in fired clay, dating back to 4800 BC. Could any other analytical investigation independently confirm when exactly this important innovation spread within the region?

Another direct evidence of mass production and specialization of ceramic production is the use of multi-chambered kilns in the firing process. This innovation, too, is very important for studying the standardization of ceramic production. Did the new kilns have any specific role in the evident change of the finished products?

In January 2009, the ceramics found in the stratigraphic test Trench VII-TP07 **(Fig. 1)** underwent a palaeo-technological study. This trench was well excavated and satisfactorily recorded. It exposed at the bottom the latest phase of the Late Neolithic, soon followed by Transitional Chalcolithic layers.

As mentioned above, the most obvious change **(Tab. 1)** was that the fine, comparatively softer Late Neolithic Buff Ware (painted brown-on-buff, Sialk I type) of the layers immediately above the virgin soil **(Fig. 2, layer TP07-7023 and TP07-7017)**, starting from layer 7021, was somehow suddenly replaced by the sturdy, Black-on-Red painted ware commonly associated to the Transitional Chalcolithic period. Examples for reference are visible in **Fig. 3**, from layer TP07-7020 to TP07-7015. The problem, as stated above, was whether this specific change involved a replacement of raw materials, or was rather the consequence of the refinement of the firing technology, so fully revealed by the discovery of the well-constructed pottery kilns of this specialized site. Were the distinctive Transitional Chalcolithic ceramics fired at higher temperatures than the softer late Neolithic wares? Which forming techniques were on record in Trench VII-TP07, and how did such techniques change in time?

Materials and methods

In order to answer these questions, the whole collection from Trench VII-TP07 (totaling 1236 potsherds: **Tab. 1**) was inspected during 2 weeks in the laboratory of the Institute of Archaeology, Tehran University. Some layers had very few sherds (for example, 7023, 7022, 7009) while others were relatively rich (7020, 7018, 7013). The sequence is bracketed between the Late Neolithic (layers 7023-7022) and the Transitional Chalcolithic (layers 7021-7004).

In general, ceramics were highly fragmented, and this did not allow a conclusive interpretation of important aspects of pottery construction technology (particularly difficult, in some cases, was the distinction between Sequential Slab Construction (hereafter SSC) and coiling).[5] Potsherds were divided

[5] See infra and Vandiver 1987; Vandiver 1995.

Fig. 2
Tepe Pardis. Late Neolithic Brown-on-Buff painted ware from layer TP07-7023 and TP07-7017 (photo: M. Vidale)

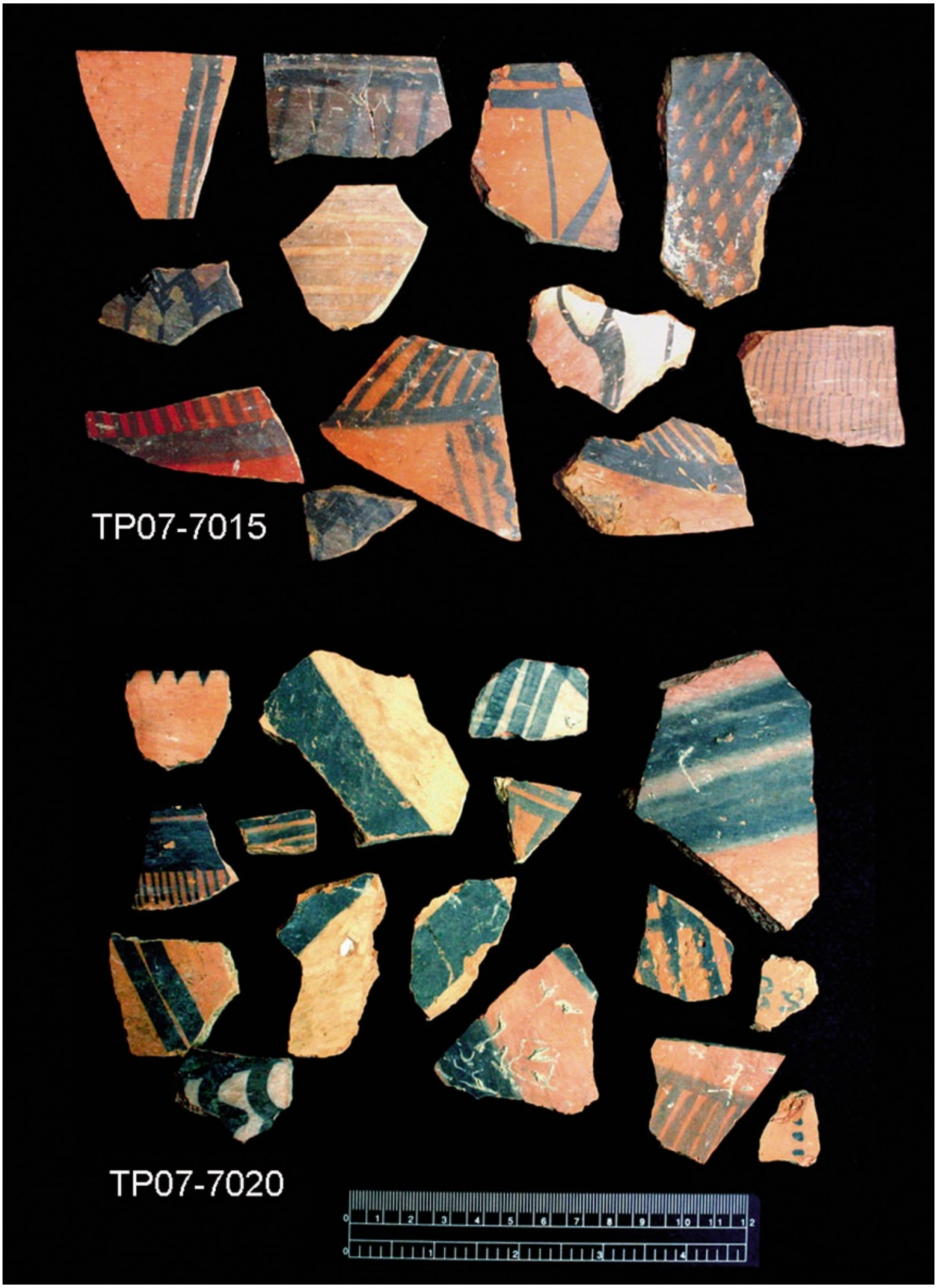


Fig. 3
Tepe Pardis.
Black-on-Red painted ware from layer TP07-7020 and 7015 (Transitional Chalcolithic) (photo: M. Vidale)

layer	unpainted, nr.	unpainted, %	painted, nr.	painted, %
7004	22	31%	49	69%
7005	31	47%	35	53%
7006	40	58%	29	42%
7007	77	87.5%	11	12.5%
7009	1	–	3	–
7013	88	51.5%	83	48.5%
7014	16	46%	19	54%
7015	57	56%	45	44%
7017	75	65%	40	35%
7018	250	70%	107	30%
7020	93	60%	63	40%
7021	92	60%	61	40%
7022	10	77%	3	23%
7023	17	65%	9	35%

Tab. 2 Tepe Pardis, distribution of painted vs. unpainted potsherds in number and percentage across the sequence

in gross technological classes, to be seriated across the sequence, notwithstanding the unbalanced distribution of the potsherds' amount in some layers. The fracture surfaces of all sherds were carefully scrutinized under oblique light using a strong lens for enhancing joins and orientation of the main inclusions, thus gathering useful information on the manipulation of clay and the vessels' forming processes.

Substantial samples of the two main classes (Chalcolithic Black-on-Red Painted and Unpainted) were selected for a more detailed description, and the information was entered in a general data base. The percentages of potsherds so recorded varied from a minimum of about 15% to a maximum of 30% of the total number of potsherds found in each layer (layers having a limited number of ceramic specimens where recorded *in toto*). Recorded information includes measurements of the sherds' thickness, some features of surface treatment, width of brush-strokes and their variations, maximum size of vegetal temper particles visible in fracture, Munsell coding of surfaces of the core, slips and paints. Linear measurements were taken with a digital caliper recording 2 digits after the mm.

8 small potsherds, selected among the smallest and least diagnostic, but relevant to answer specific technical issues, underwent further analytical investigation. In detail, 2 of these potsherds were prepared for thin section analysis for inspecting their mineralogical-petrographical features; 4 were analyzed by the means of X-rays Diffraction (XRD), for determining their main mineralogical components; 5 were prepared in form of polished cross sections and underwent Scanning Electron Microscopy (SEM-microprobe) investigation; 6, finally, were X-rayed with a mammographic machine, investigating their inner structure in terms of forming technology.

Main technological trends and ceramic classes

Table 2 shows that the average percentage of painted specimens in the Neolithic layers (TP07-7023, 7022) is 29%; in the Transitional Chalcolithic (TP07-7021, 7020, 7018, 7017, 7015, 7014, 7013) it is 42%, and in the Chalcolithic horizons (omitting TP07-7009, layers TP07-7007, 7006, 7005, 7004) 44%. Thus, painted pottery, in the considered sequence, is in slow but constant growth from the earliest layers to the top. The main technological classes on record may be described as follows.

1. Coarse Chaff-Tempered Unpainted ware is found from the earliest layers (7023 and 7022, Late Neolithic) to the topmost layers of the trench. This ware is thick (1–2 cm) and very porous. The surface, as a rule, is untreated. The vegetal particles are rather long, the maximum length visible on fracture averaging about 15.4 mm. It is fired in incomplete oxidizing atmospheres, the surface colours wavering from very pale brown (10YR 8/3, 10YR 7/4) to light brown hues (7.5YR 6/4). Few fragments show a reduced core.
   The oldest specimens belong to 1 or more large cylindrical containers made with slabs or perhaps coils with butt and dove-tail joins, their height ranging from 2.8 to 3.9 cm. In our limited sample, in the 2 lowermost (Late Neolithic) layers this ware represents almost 70 % of the total. Thus, Coarse Chaff-Tempered Unpainted ware included most utilitarian containers. In the following phase (Transitional Chalcolithic, layers 7021-7013) the percentage falls to 7 %, suggesting that the use of similar coarse containers was more restricted and specialized. In the upper layers (from 7017 upward), a variety of coarse chaff-tempered sherds come from globular or sub-cylindrical vases with a simple or flat expanded rim. They are similar to the older specimens of similar construction, but many potsherds are over fired, and the core is strongly reduced.
   While the exterior may be pink (5YR 8/4), to light gray (10YR 7/2), the interior varies from the same light gray to dark gray (10YR 3/1), reflecting the use of these coarse vessels, fired in reducing atmospheres, in one or more pyrotechnological activities. On the whole, this group amounts to

almost 35 % of the assemblage of layers 7009-7004. But such high incidence **(Tab. 1)** might well be a statistic "artefact" due to the accidental breakage on spot of few large coarse vessels of this type. A unique coarse chaff-tempered potsherd generically belonging to this class was moulded into a basket (see below).

2. Late Neolithic Buff Painted ware. In the Late Neolithic horizons this fine ware **(Fig. 2)** includes open hemispherical bowls and represents about 30 % of the total. In the Transitional Chalcolithic layers, the percentage falls to little more than 4 %, to disappear in the uppermost contexts. The ware is soft, with abundant chaff temper. Vegetal bits are abundant and have a maximum visible length averaging 7–8 mm.

   The forming technique appears to be SSC, the surface often showing faint rotation marks. Late Neolithic Buff Painted ware is slipped and carefully polished both inside and outside. The slips, 0,7–1,2 mm thick, are white (10YR 8/2) to very pale brown (10YR 8/3, 8/4) or pale brown (10YR 6/3). The surface is intensively polished, the streaks being quite regular and running parallel to the horizontal tangency plane of the mouth. The colour of the paint is dark gray (10YR 4/1) to very dark grayish brown (10YR 3/2). In some specimens the paint faded to very light gray shadows. Decoration, on the exterior as well as on the interior, was carefully painted with horizontal and vertical bands tied like a basket weave with series of short parallel segments and series of wavy lines. The designs are made with brushstrokes averaging in thickness 2.2 mm. Apparently the painters consciously combined lines and segments of slightly different width: sometimes, larger lines (2.2–2.8 mm) were used for defining the bands, while series of thinner strokes (1.4–1.8 mm) filled the same bands **(Tab. 3)**. These moderate variations in width were probably obtained using from different sides the same type of flat brush. The graphics thus created provide a simple but pleasant contrast. In layers TP07-7023 and 7022 this ware was found together with the earliest sherds of the later reddish wares.

3. Chalcolithic Unpainted and Black-on-Red Painted ware. This class **(Fig. 3)** has a more compact, sturdy fabric. Its surfaces are slipped and highly polished before firing. A fair percentage of the sherds is painted (see **Tabs. 1**; **2**) and we presume that a good amount (if not all) of unpainted sherds came from the plain sections of relatively large painted vessels. The outer slipped surface is often reddish yellow (5YR 6/6, 7.5YR 6/6) or reddish brown (2.5 YR 6/4, 5YR 5/4, 5YR 6/4). Well represented are shadows described as pink and pinkish gray, red, light brown, light yellowish brown and brown. Finer wares were fired in uniform oxidizing conditions. About 30% of medium-coarse sherds have reduced cores (colours ranging from gray or dark gray, 5YR 6/1 and 10YR 5/1, 7.5YR 4/0 and the like, to pinkish gray and light brown, 7.5YR 6/2 and 7.5YR 6/4). The maximum length of vegetal inclusions, in the Transitional Chalcolithic and Chalcolithic layers, averages 6.4 mm. Chaff temper was chopped finer in this class that in the previous Brown-on-Buff Painted ware. The colours of the painted decoration are in the majority of the cases dark gray (2.5 YR 4/0, 5YR 4/1, 7.5 YR 4/0) or very dark gray (2.5 YR 3/0, 5YR 3/1, 10YR 3/1). Other shadows, much rarer, include weak red, gray, dark brown and brown.

Layer TP07	Av. Max. width	Av. Min. width	Deviation
7004	10.54	3.38	7.16
7005	4.92	1.20	3.72
7006	4.34	1.49	2.85
7007	5.09	1.54	3.55
7014, 7013	4.38	1.70	2.68
7015	7.79	2.54	5.25
7017	6.02	2.49	3.53
7018	6.36	2.78	3.58
7020	8.69	2.87	5.82
7021	6.44	2.70	3.74
7023, 7022	2.67	1.73	0.94

Tab. 3
Tepe Pardis, TP07. Average maximum and minimum width values of brush strokes across the sequence and deviation between the two values. The difference, minimal in the Late Neolithic layers (7023 and 7022), shows that the differentiation of brush strokes' thickness, at the beginning, was poorly developed. With the Transitional Chalcolithic painted lines became soon thicker. The use of traits of different thickness developed during the Transitional Chalcolithic, up to the uppermost layers of the Trench

Tab. 4
Tepe Pardis, TP-07. Potsherds with strong wear on the fractures, recycled, identified as possible pottery making tools. TP07-7015 was probably used with a fast rotating potter's wheel

layer	size (in cm)	shape	wear location	wear location to rim
7017	8.4 × 6	hexagonal	2 sides	right and left
7015	8 × 5	hexagonal	3 sides	right
7013	2.3 × 1.9	trapeze-like	2 sides	–
7013	1.6 × 1.4	quadrangular	4 sides	–
7013	3.5 × 2.4	trapeze-like	1 side	left
7013	3.7 × 1.5	lunate	2 sides (with crescent)	–
7013	2 × 1.2	trapeze-like	1 side	upper side (on rim)

We recorded the variations of the maximum and minimum width of brush strokes or bands across the pottery sequence. The diffusion of Chalcolithic Black-on-Red Painted ware initially involved the tracing of larger bands (the average maximum width rises from 2.2–2.8 mm in the late Neolithic vessels to more than 7 mm in the lower layers of the Transitional Chalcolithic, if we consider together TP07-7021, 7020, 7018, 7017, 7015). In the last 2 layers ascribed to the Transitional Chalcolithic (TP07-7014, 7013) the value drops to 4.38 mm. At the same time, the minimum width of the lines drops to 1.70. These variations depend on the frequency, in these layers of, Chalcolithic Very Fine Painted ware (the following class).

The maximum width of bands or lines remains rather low in the following Chalcolithic layers (TP07-7007, 7006, 7005), on average 4.90 mm. Painted bands and lines get thicker again in the surface contexts labeled TP07-7004 and 7003; in layer 7004, the divide between the two types of traits grows again. The painting performance, when painters traced bands and fields with thicker lines and filled them with thinner brush strokes, suggests a further step towards standardization. At the same time, one notes the regular and constant decrease of the minimum width of brush traits from layer 7020 to the 7005.

4. Very Fine Painted ware. Looking again at **Tab. 3**, the use of tiny strokes (and quite possibly of finer brushes) follows the diffusion of the finest painted and better fashioned vessels in layers TP07-7015-7013. In these pots, lines are often very thin, almost hard to be seen on the present surface of the vessels. Designs are linear, and their thickness variations play a minor role. This explains the low deviation between the two values in the materials of layers TP07-7014 and 7013. The paste is very homogeneous and the maximum length of the vegetal inclusions measured in this group is 4.9 mm, against the average value of 6.4 of the painted potsherds of the Transitional Chalcolithic and Chalcolithic, confirming that their fabric is particularly fine.
5. Other ceramic classes are scarcely represented. They include few potsherds of a Buff unslipped Ware **(Tab. 1, Transitional Chalcolithic)** and some fragments of a very distinctive Black Burnished ware, found the earliest layers of the Transitional Chalcolithic. Their frequency in layer TP07-7018 is somehow deceptive, because most of the 8 potsherds actually come from a single smashed vessel, a kind of small carinated bowl. The black colour, at a visual inspection, might be due to high percentages of an organic component.

Analytical results: base materials

Any research aimed at defining the nature of the raw materials used in ceramic production, their provenience and technological constraints would require a broad geomorphological and sedimentological survey of the surroundings of the site, as well as a systematic sampling of natural sediments and various types of archaeological finds (from clays used in architectural buildings to kiln materials, ending with selected finished ceramics). In this occasion, provenience is out of our scope, and we limited the research to the preliminary archaeometric tests listed above, mainly aimed at investigating ceramic technology and its change in time.

As stated above, we prepared 5 potsherds – one of the Late Neolithic Buff Ware class, the other 4 of the Painted Chalcolithic class – for observing them in polished section, and comparing them to the 2 samples cut in thin sections. Polished stratigraphic sections were observed at the mineralogical microscope and at SEM. Thin sections were studied at the polarizing mineralogical microscope. The same 4 potsherds were then sampled and the detached chips powdered for XRD analysis, in order to characterize their mineral contents.

Cross sections of Brown-on-Buff Painted ware and Chalcolithic Black-on-Red Painted ware immediately show a basic difference. The first sherd **(Fig. 4-5, TP07-7023)** is very porous, because of the abundant and rather coarse vegetal temper. The fibers appear parallel to the planar surfaces of the sherd (i.e. the inner and outer surfaces) but locally their orientation is less regular (fibers are at low angles with the same surfaces). This suggests SSC: each pressed slab or clay layer has parallel fibers but at the joins, where the slabs are freely manipulated, the orientations diverge. Although some specimens show a reduced core (from pinkish gray 7.5YR 7/2-6/2, to pale olive, 5Y 6/4), firing is more often uniform. Tiny red iron oxide particles are evenly distributed in the core and secondary reduction effects are visible as limited halos around the largest vegetal particles. In polished section the outer slip appears as a darker grayish layer, about 500 µm thick, with tiny mineral inclusions **(Fig. 4)**.

In contrast, the polished section of a Chalcolithic Black-on-Red Painted sherd from the same lowermost layer **(Fig. 6)** shows a lesser amount of shorter and thinner chaff fibers. The paste, as a consequence, is much less porous. Vegetal particles are parallel to the sherd's surfaces and more regularly oriented. Porosity is limited to the grey reduced core: reduction halos, like in the former potsherd but more evidently, surround the burnt fibers. The vessel was fired at length in reducing atmospheres, to be intensively re-oxidized at the end.

Fig. 4
Tepe Pardis. Polished section of a Brown-on-Buff painted sherd from TP07-7023 (late Neolithic). 5 X.

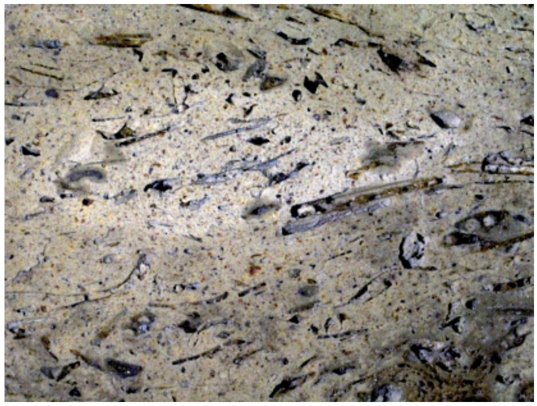


Fig. 5
Tepe Pardis. Polished section of a Brown-on-Buff painted sherd from TP07-7023 (late Neolithic), see also **Fig. 7** (3 X).

Fig. 6
Tepe Pardis. Polished section of a Black-on-Red painted Chalcolithic sherd from TP07-7021 (6 X)

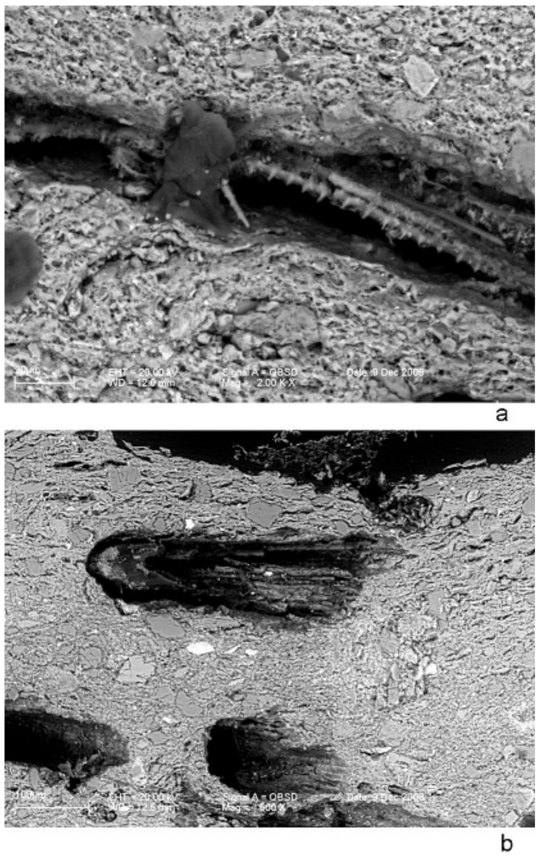


Fig. 7
Tepe Pardis. SEM pictures of Black-on-Red painted Chalcolithic sherd from TP07-7021, showing vegetal particles within elongated pores at different magnification. In Fig. 7b the vegetal particle is incompletely burnt

While in many pores vegetal material was completely burnt, SEM pictures **(Fig. 7)** clearly show residues of well preserved vegetal tissues. On both sides of the polished section of **Fig. 6**, above and below the inner gray core, one sees two wavy layers applied in semi-fluid conditions, about 400–450 μm. These slip-like surfaces are very fine and almost free of vegetal material. Details of the same sections show more evidence of the surface finishing processes. **Fig. 8** shows 1–2 layers of a fine slip on the interior, without temper, and the uppermost layer formed by polishing the vessel's walls before firing. On the outer surface **(Fig. 9)** the darker film is the pigment, on average 160–240 μm thick.

In 2 cases out of 3, SEM elemental maps showed that pigments on Chalcolithic Black-on-Red Painted sherds are iron-manganese oxides. The pigment is well visible, in cross section, in the SEM pictures of **Fig. 10**, where heavier elements appear as lighter-coloured phases. The paint is about 100 μm thick, and the manganese-rich phase is visible as a thin upper film.

In the sections of Chalcolithic wares, lighter particles are iron and iron-titanium compounds scattered in the paste. The SEM picture of **Fig. 11** (a sherd from TP07-7021) shows an iron-titanium spherule whose developed dendritic structure is probably due to a long exposure to high temperature while firing.

Comparing Late Neolithic Buff Ware and Chalcolithic wares in thin sections, the former have a yellowish paste with scattered fine iron oxide particles **(Fig. 12,a–b)**. The temper includes very fine microcrystalline quartz and feldspar angular grains (average diameter <50 μm, and coarse silt between 0.06 and 0.04 mm), with fine sand particles.

The sample of the second class **(Fig. 12,c–d)**, distinguished by the strong red colour of both surfaces, includes a temper of fine mono-crystalline angular quartz grains, K-feldspar and plagioclase

Fig. 8
Tepe Pardis. Polished section of a Black-on-Red painted Chalcolithic sherd from TP07-7021, detail of the inner surface with polishing layer (3 X)

Fig. 9
Tepe Pardis. Polished section of a Black-on-Red painted Chalcolithic sherd from TP07-7021. Deatil of the external surface with paint layer (2.5 X)

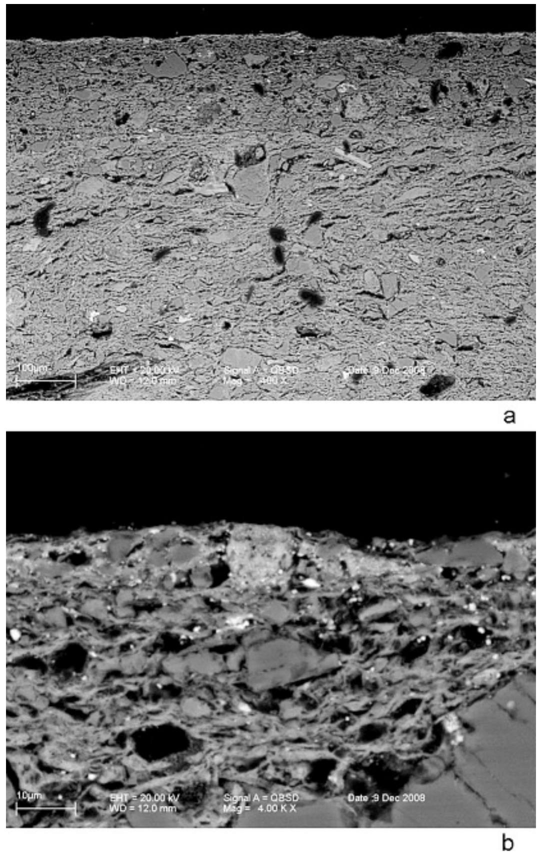


Fig. 10
Tepe Pardis. SEM pictures, at different magnification, of the section of the exterior surface of a Black-on-Red painted Chalcolithic sherd from TP07-7021, showing the paint film. The lighter phase on the surface is relatively rich in manganese. A cubic crystal rich in manganese is seen in **Fig. 10b**

grains, sheets of brown mica, and finally, poly-crystalline quartz and chert particles (from sporadic to rare). Also in this case the temper is very fine, the grain diameters in general being <50 µm. All inclusions are uniformly spread into the paste.

Considering the samples of both classes, the components that were not transformed at high temperature during the firing process are the following: quartz, feldspar, mica. The secondary phases created by solid-state reaction between clays, temper and flux components (neo-formed) include calcic plagioclases, diopsidic pyroxenes and gehlenite; these latter allow some inference on the firing temperatures of the analyzed ceramics. In fact, they formation is due to the gradual decomposition of calcium-rich inclusions and their reaction with the aluminum-silicatic fraction. This explains the optical inactivity of the background paste (that appears dark brown, in the thin sections images taken at crossed Nichols) and the appearance, in the place of the original calcium-rich particles, of shapeless or rounded pores replacing the imprint. This evidence preliminarily suggests that in both classes the firing temperature range was relatively high (above 850 °C).

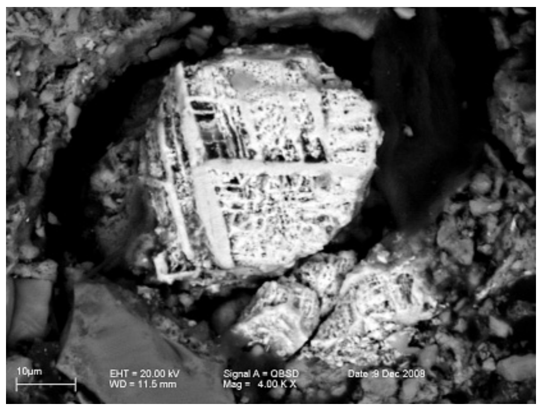


Fig. 11
Tepe Pardis. SEM picture of the core of a Black-on-Red painted Chalcolithic sherd from TP07-7021. Detail of a titanium-iron spherule with inner dendritic structure, secondarily formed because of the exposure of the vessel to high firing temperatures for long times

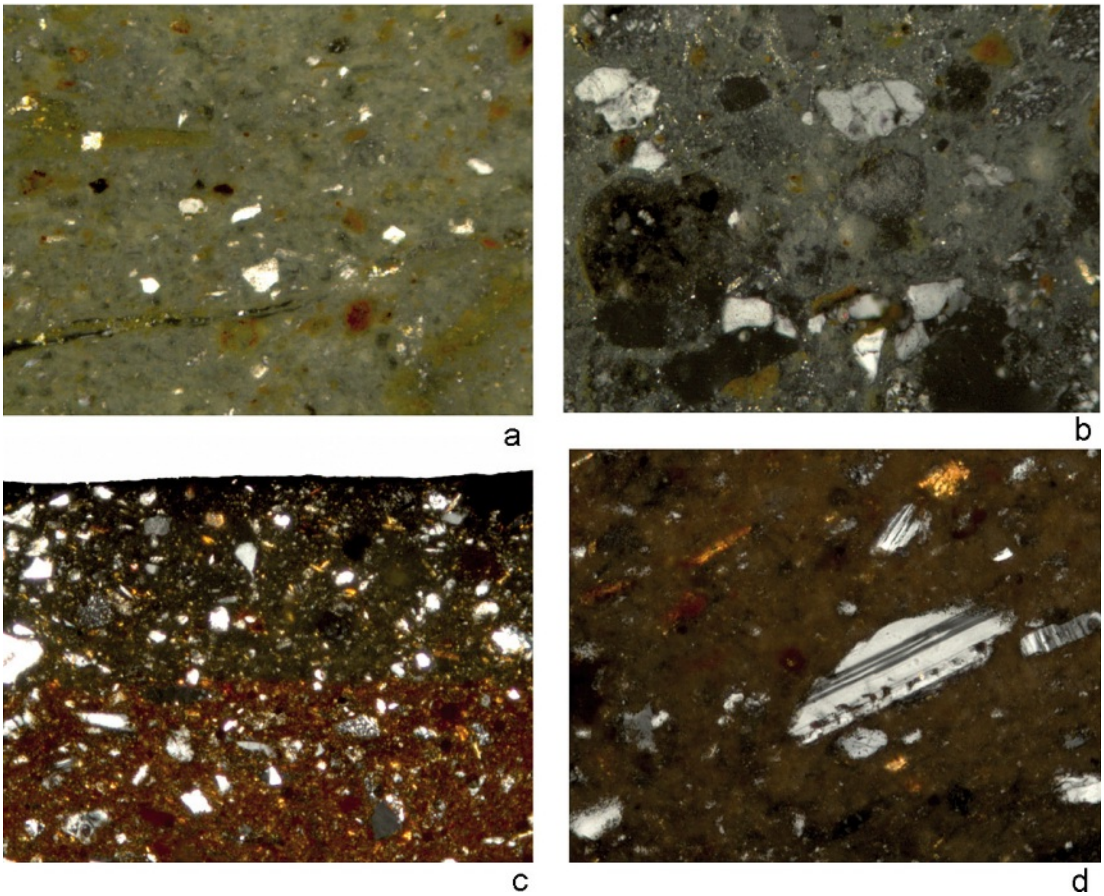


Fig. 12
Tepe Pardis. a, Thin sections at the mineralogical polarizing microscope, sample of Brown-on-Buff painted sherd from TP07-7023, late Neolithic (10 X, crossed Nichols); b – sample of Brown-on-Buff painted sherd from TP07-7023, late Neolithic (10 X, crossed Nichols); c – Black-on-Red painted Chalcolithic sherd from TP07-7021, Chalcolithic (10 X, crossed Nichols); d – Black-on-Red painted Chalcolithic sherd from TP07-7021, Chalcolithic (20 X, crossed Nichols)

This is generically supported by the first XRD tests (**Fig. 13**: the uppermost is a Late Neolithic Buff Ware Painted sherd from TP07-7023, the other 2 below are samples of Chalcolithic painted ware respectively coming from TP07-7021 and 7020). Mineralogical components (quartz, feldspars – both K-feldspar and plagioclase – diopside and gehlenite) are the same. The composition is basically similar, with some difference in the relative abundance of the detected mineral phases. In the Late Neolithic Buff Ware Painted sample (layer TP07-7023) the amount of diopside (marked as pyroxene) and gehlenite seems higher. But as these minerals are secondary (i.e. newly formed at high temperature), this does not imply that the sedimentary basins of the clays were different.

Finally, although grog (crushed pottery) is hardly identified with analytical means, few potsherds show ceramic flakes on fracture. It is clear that sometimes pottery was ground and added to clays as temper. This form of ceramic recycling is not uncommon in Chalcolithic Black on Red Painted ware. It was observed in 3 cases in layer TP07-7018 (a large globular vessel and 2 non determinable sherds), in layer 7017 (a fragment of a large container), and in layer 7006 (a rim fragment and the base of a jar).

Forming techniques: basket moulding

This technique is documented by a single but distinctive potsherd **(Fig. 14)**, found in layer TP07-7013 (uppermost layer of the Transitional Chalcolithic). **Fig. 14** shows the interior of the potsherd (above), with positive imprints of the fabric of a finely woven basket. The exterior (below) is plain. The pottery is coarse, chaff tempered and fired in partial oxidizing conditions. Moulding onto stones, gourds and baskets is a very ancient ceramic forming technique in Asia, most probably dating back, in China, to the earliest Neolithic settlements at the beginning of the Holocene.[6] Variations of this technique are reported, in the time range 6000–3000 BC, from

[6] Wang 1995.

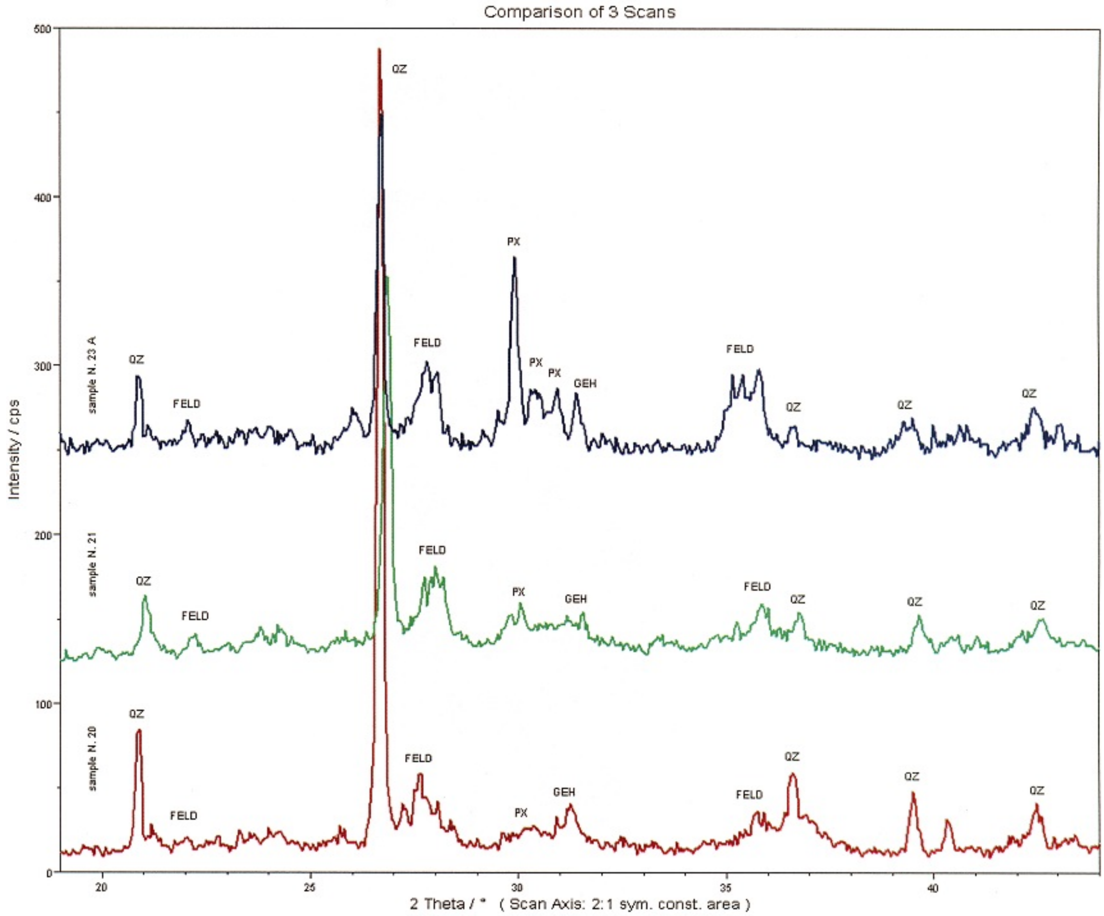


Fig. 13
Tepe Pardis, TP07-VII. Comparison among three XRD runs, respectively for a sample of Brown-on-Buff painted sherd from TP07-7023 (late Neolithic) (black, on top), a Black-on-Red painted Chalcolithic sherd from TP07-7021 (green, middle) and Black-on-Red painted Chalcolithic sherd from TP07-7020 (red, below). The mineral components are the same, but TP07-7023 has a higher amount of pyroxenes (diopside) and gehlenite

China to northern Pakistan and north-eastern India;[7] between the fourth and the third millennium BC it was very common across the whole mountain ranges of Baluchistan and in Makran, up to the Bampur valley. Also in the Marv Dasht plains, Fars, basket moulding techniques are well attested in Jari A/Bakun B contexts, dating the fourth millennium BC.[8] At Choga Mish, baskets were used for making coarse chaff-tempered vessels ("layered" wares) in the Archaic Susiana phase, i.e. from the late sixth to the mid fourth millennium BC. The manufacturing technique encountered at Tepe Pardis was discussed by Delougaz and Kantor at Choga Mish[9] and commented in greater detail by Vandiver[10] describing the manufacturing technology of the earliest ceramics of Mehrgarh, Pakistan (Period IB, about 5500–5000 BC). Slabs of clay were pressed within baskets acting like a concave moulds. Formed vessels were left to dry and as they shrunk were removed from the interior of the containers. As a third step, an outer layer of clay slabs was pressed against the exterior of the unbaked vessel, thus retaining the positive imprints of the wicker fabric. The presence of this ware at Tepe Pardis stresses the wide geographical and chronological distribution of this forming technology and calls for a better technological and cultural definition of its evolution.

Sequential Slab Construction (SSC) and coiling

The ceramics from Tr. VII-TP07 are, obviously enough, almost entirely hand-made. Technical approach to vessel construction involved, as observed in other archaic ceramic industries of the Iranian Plateau, the pre-forming of small lumps, their flattening into slabs of various shape and the careful joining of the plastic lumps to form bases, walls and rims. However, the geometrical shape of the forming slabs,

[7] Sharif/Thapar 2000.
[8] Alizadeh et al. 2004, Fig. 4.
[9] Delougaz/Kantor 1996, pl. 205,A–D.
[10] Vandiver 1995.

Fig. 14
Tepe Pardis.
A fragment of a vessel moulded within a basket (TP07-7013) (photo: M. Vidale)

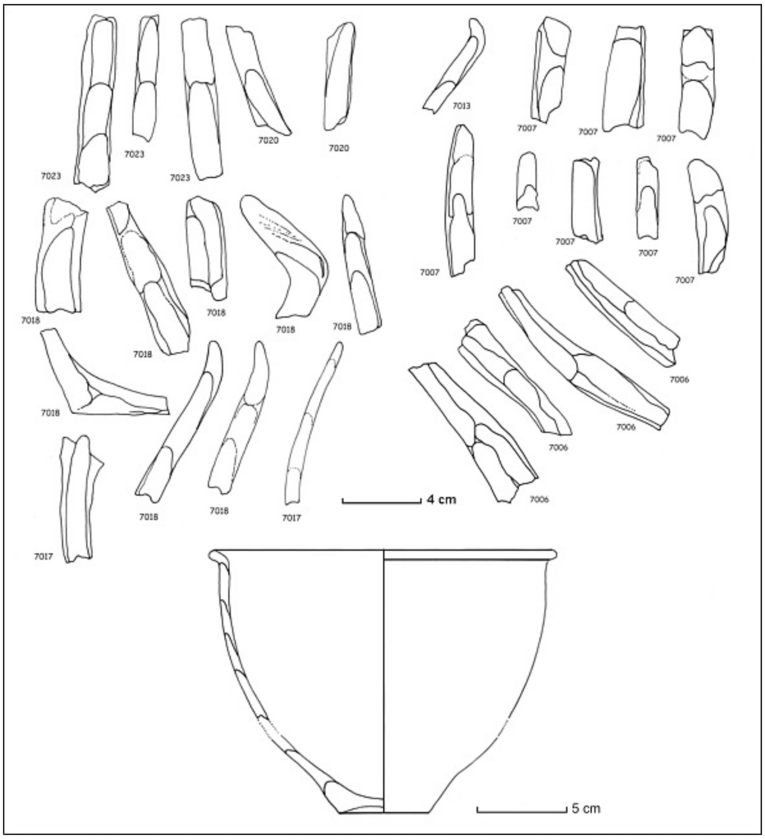


Fig. 15
Tepe Pardis, TP07-VII. Sections of potsherds built with Sequential Slab Construction and coiling processes, from various stratigraphic contexts, and (below) of a bowl from layer 7004. The inner structure of this bowl suggests a construction process by the means of superimposed coils (drawing: M. Vidale)

without a systematic use of radiography, is quite hard to define. In particular, a technical distinction between such slabs and "coils", when ceramics are highly fragmented, is often questionable. Actually, how do we define technically a coil?

Pamela Vandiver, who thinks that the beginning of ceramic production in South Asia from the sixth millennium onwards depended upon a conservative attachment to SSC techniques,[11] originally described a coil as "... a preformed element ... round in section, that when joined can be pressed so that it flattens out ... no more than two or three times its original diameter. Furthermore, the planar length of a coil (when viewed from the surface of the pot) is generally ten or more times its planar length."[12] By definition, this approach restricts the possibility of identifying coils to the rare case of unbroken vessels, or to quite large potsherds.

When X-rays imaging techniques were applied to a sample of ceramics collected on the surface of Cheshmeh-Ali (IsIAO, Rome)[13] the potsherds' inner structures included both round, oval or polygonal slabs, about 4 cm in diameter, and flat longer elements, possibly measuring around 5–6 × 3 cm. Placed on the vessels' rim, such long slabs showed on surface regular rotation. Hypothesizing the use of a fast rotating device, the authors suggested that such long slabs were "proto-coils". This may be relevant for the ceramic industries of Tepe Pardis, because Cheshmeh-Ali is only 25 km NW of our site, and the Rome materials, stylistically datable to Cheshmeh-Ali Transitional Chalcolithic, approximately 5200–4600 BC, are partially contemporaneous with the assemblage from Tr. VII-TP07.

While at Tepe Pardis SSC is the basic forming technique, and longer slabs could have been used as "proto-coils", some vessels may have been built with a regular, standardized coiling process. In fact, as the fine painted conical goblets of Susa I (early fourth millennium BC) were doubtless built with coils carefully fashioned on a fast potter's wheel,[14] there is little wonder that this technique was deeply rooted in the craft know-how of the Iranian Plateau of the fifth millennium BC. Given the highly fragmentary state of the Tr. VII-TP007 sherds and their high degree of finishing or polishing, joins were quite difficult to identify from the planar view. In contrast, thanks to the rich vegetal temper content of most of the specimens and the often fast manipulation, many sherds show in section the shape of the assembled elements **(Fig. 15)**.

These sections demonstrate the use of a SSC technique only when more slabs are superimposed one above the other in a single point of the wall, like in the coarse chaff-tempered jar walls of **Fig. 24**, layer 7006, or the fragment in **Fig. 23**, layer 7018, in the centre. Here the wall was built by superimposing and squashing three thin slabs about 5–7 mm thick (this technique creates, in the words of Vandiver, "an overlapping join of three manufacturing elements").[15] In the other specimens, preformed lumps with variable butt joins could be either coils (if reasonably long) or elongated slabs. If they were elongated slabs, as they should be if we follow Vandiver's arguments, then the complex features visible in the cross-section in **Fig. 15, layer 7007** might be broken ends of butt joins. In the contrary case, they might be coils, superimposed by the means of a buffer layer of very plastic clay. Only larger potsherds and more X-ray images might solve the question. Another feature of the assembling technique at Tepe Pardis are flimsy clay layers applied to smooth and wrap up the joins, as in **Fig. 15, layers 7023, 7018 and 7017**. These clay films, 1-2 mm thick, have nothing to do with slips

11 Vandiver 1987; Vandiver 1995.
12 Vandiver 1995, 649.
13 Dipilato/Laneri 1988.
14 Laneri 1997.
15 Vandiver 1995, Fig. 1.

and probably were applied as soft, very plastic clay during the construction sequence.

The collection is too small, and the evidence too far from resolving, to allow any inference on the chronological distribution of coiling vs. SSC processes. However, coarse chaff tempered jars were built with SSC also in the uppermost layers of Tr. VII-TP07 **(Fig. 15, layer 7006)**. On the other hand, in a large red-slipped hemispherical pot found near the surface **(Fig. 15, layer 7004)**, reconstructed almost entirely, the butt and dove-tail joins observed in fracture show a very regular sequence of added elements. Strips are higher in the lower part and narrow near the mouth of the vessel. This very regular construction leaves little doubt that the vessel was built with a series of pre-formed coils rather than with a free superimposition of discrete slabs.

Furthermore, positive evidence of the coiling process comes from 2 potsherds, respectively found in layers TP07-7017 and 7018. The first fragment (from 7017, **Fig. 16**) shows on fracture the butt end of coils at the inflection in the lower part of a large bowl or jar. The cross section shows three superimposed joins of the same fashion, suggesting that the entire lower portion of the vessel was made with elongated coils, rather than slabs. The second sherd shows on the upper and lower edges sequences of round depressions **(Fig. 17,A)**. Joins modified in this or similar fashions are typical of jars or basins assembled in sections (a later example was observed at Shahr-i Sokhta, Period II).[16] Wavy or tipped edges increase the contact surface and give strength to the join. The impressions on this sherd (from layer 7018) would make no sense on a single slab, but would be quite functional on a long coil, where the impressions would have been rapidly made before the clay could dry.

Moulding on upturned (convex) pots

Finally, in the sequence there are 3 potsherds (two of which are illustrated in **Fig. 17,B.D**) that were probably paddled and shaped against convex moulds, most probably an upturned ceramic vessel. One comes from layer 7020, Transitional Chalcolithic, and belongs to a thick chaff-tempered container. The cross section shows 3–4 slabs applied one to the other, while the inner (convex) surface, free of any tool, hand or rotation mark, with the voids left by vegetal temper parallel to the surface, suggests that clay was beaten against a convex object. Similarly, a sherd from layer 7018 shows a thin coating of dry clay and sand on the inner surface, most probably applied for making easier the detachment from a similar mould. Finally, the ring foot of a vessel from layer 7005 **(Fig. 17,C)** shows on the outer surface a regular series of thin and regular lines, signs of a fast rotation, but the interior surface is perfectly rounded and free from any mark. This foot was fashioned out of a clay slab pressed against a hemispherical "mould" in pottery or wood, and centered on a potter's wheel.

We are not very familiar with these possible indicators of paddling and moulding, particularly on assemblages of similar antiquity. It is possible that at Tepe Pardis and in other Chalcolithic settlements of the region techniques of similar description were more frequent and had a longer tradition than we can presently envisage. However, the discovery of a basket-marked fragment in layer TP07-7013 indicates that the principle of moulding might have been used in different construction techniques. Ethnoarchaeological accounts of the construction of vessels by paddling clay onto upturned pots (central-western Africa) are provided by Gallay.[17]

Early evidence of fast wheel-throwing

The mass of the TP07 ceramics, as stated above, was fashioned by hand building. Nonetheless, while studying the assemblage, we noticed 2 potsherds (ascribed to the Black-on-Red Painted class) with anomalous features. We hypothesized that the original vessels had been fashioned by fast wheel-throwing. These 2 potsherds are described as follows:

TP07-7021 **(Fig. 18)**. Rim fragment of a bowl. The fabric is fine, with little mineral inclusions and fine chaff particles. The sherd is covered with a fine light brown slip (7.5YR 6/4) and the interior is oxidized. It is painted on the exterior with 2 sets of horizontal bands (dark brown, 7.5YR 4/2). Both the outer and inner surfaces are covered by regular bands of regular, parallel fine rotation marks.

TP07-7018 **(Fig. 20)**. Wall fragment of a fine vessel, with undetermined form. The fabric is particularly fine, homogeneous. Only rare and isolated chaff particles are visible in fracture. Originally covered by a thick yellowish red slip (5YR 5/6); the paste is reddish yellow (5YR 7/6). The thickness is included between 2 and 3 mm and contrast with the thicker walls of the rest of the assemblage. Both the outer and inner surfaces are covered by regular bands of parallel fine rotation marks. If the slip were completely preserved, such surface features would have been hidden and invisible.

16 Salvatori/Vidale 1997, 57.

17 Gallay 1981.

Fig. 16
Tepe Pardis, TP07-VII, layer 7017. The fracture shows the butt join of a long coil, demonstrating a regular construction process by the means of coiling (photo: M. Vidale)

Both sherds are dated to the early Transitional Chalcolithic deposits. Given these anomalous features, the 2 potsherds underwent XR analysis by a mammographic device, following the method already applied by Dipilato and Laneri[18] for the Cheshmeh-Ali potsherds in Rome. Radiographic structural indicators of various manufacturing techniques were discussed by Hultén, Alexander and Johnson, Vandiver, Carr, Henrickson, Carr and Riddick, Desogus, Laneri, Laneri and Vidale, Levi, Berg and many others.[19]

In short, and oversimplifying, irregular structures made of polygonal-rounded assembled parts, enhanced by chaotic patterns of voids and inclusions, indicate SSC; sequences of thicker and thinner horizontal bands in the vessels walls, underlined by lines of elongated pores and inclusions, are considered reliable indicators of coiling; moulding is attested by critical joins and finger depressions surrounded by fine networks of cracks; while wheel-throwing creates in the wall distinctive patterns of oblique alignments of elongated voids made by air bubbles trapped in the clay. If the paste includes chaff, imprints get oriented in the same fashion. In general, such oblique alignments run through the vessels walls in a spiral-like fashion, from the base (where they appear more vertical) to the rim (where they are more horizontal). Created by the combined action of centrifugal force and the uplifting traction of throwing, oblique voids are the unmistakable evidence of fast rotating potter's wheels. XR analysis was monitored at detecting such technical indicators.

The XR plate of TP07-7021 **(Fig. 19)** shows an abundant vegetal temper. The upper part of the bowl is slightly thicker than the lower wall. While here the orientation of the chaff particles is irregular or chaotic (and thus more compatible with coiling or SSC), at the mouth the fibers are parallel and there is a weak trend towards an oblique orientation. This sherd is comparable to some fragments from Cheshmeh-Ali, where indicators of rotation became more visible near the rim.

TP07-7018 is more revealing **(Fig. 21)**. In this finer specimen, a series of oblique pores and chaff voids is clearly recognizable and demonstrate beyond any possible doubt the use of the "fast" potter's wheel in the early Transitional Chalcolithic levels of Tepe Pardis. The sense of rotation of the wheel is determined after the direction of the oblique alignments. Looking at the XR image from the planar surface (i.e. from outside, like in **Fig. 21**) the pores run to the upper right. The angle of the lines of pores and inclusions is a complex function of the turning speed, of the amount of time spent in throwing and obviously of the form (open, restricted or composite) of the manufactured vessel.[20]

Practical experiments[21] suggest that the alignments are more horizontal in vessels having a limited height, and in those thrown at higher speeds; the angles are inversely related to the rotation speed and the diameters of the revolving vessels, and directly proportional to the height of the thrown vessels. Thus, on the basis of the angles alone, and missing the complete form, it is not possible to come to positive conclusions about the revolution speed of the early potter's wheel of Tepe Pardis. Nonetheless, the angles of TP07-7018 are quite steep, and this might involve a somehow limited velocity, may be not far from the 60 rpm (rotations per minute) established many years ago by Amiran and Shenhav[22] as the actual threshold for an efficient throwing of small vessels on a simple "fast" wheel.

In the light of the above discussion, we had identified a bowl made with manual techniques (coiling or SSC), and possibly further thinned and fashioned, as a second step, on the wheel; and a case of direct fast wheel throwing.

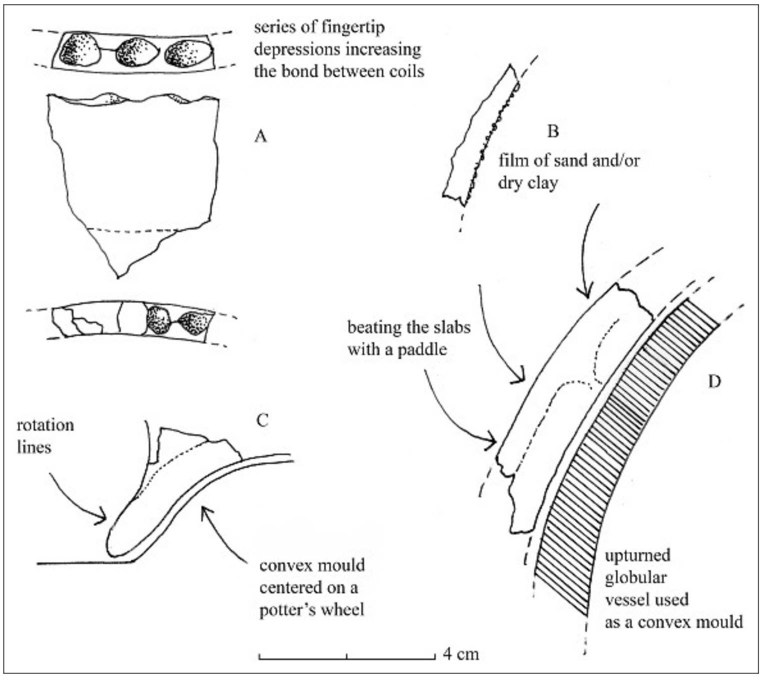


Fig. 17
Tepe Pardis, TP07-VII. Technical details in the vessels' construction processes (coiling and moulding) (drawing: M. Vidale)

[18] Dipilato/Laneri 1998.

[19] Hultén 1974; Alexander/Johnson 1982; Vandiver 1988; Carr 1990; Henrickson 1991; Carr/Riddick 1990; Desogus et al. 1995; Laneri 1997; Laneri/Vidale 1998; Levi 1999; Berg 2008.

[20] Hultén 1974.

[21] Desogus et al. 1995.

[22] Amiran/Shenhav 1984.

Fig. 18
Tepe Pardis. Fragment of a painted bowl from layer TP07-7021, exterior and interior surfaces (photo: Federica Aghadian)

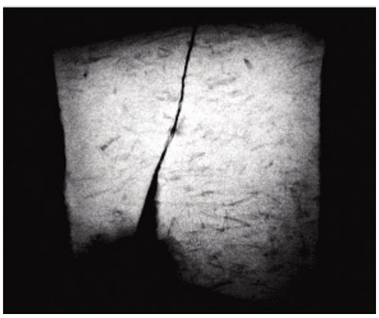


Fig. 19
Tepe Pardis. Mammographic XR image of the microstructure of the sherd in Fig. 18. The chaff inclusions have an irregular setting, but a partial orientation is compatible with turning

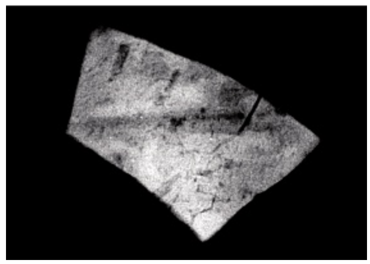


Fig. 20
Tepe Pardis. Wall fragment of a fine red slipped vessel from layer TP07-7018, exterior and interior surfaces (photo: Federica Aghadian)

Fig. 21
Tepe Pardis. Mammographic XR image of the microstructure of the sherd in Fig. 20. The oblique orientation of the inner void demonstrates the use of a fast potter's wheel

These results encouraged us to sample 4 other sherds. 2 of them had surface and construction features that suggested a rather coarse hand modelling, free from evident rotation marks (respectively from TP07-7007 and 7006). These fragments were compared with 2 other specimens (from TP07-7004) whose fashion was compatible, in contrast, with a forming process involving the use of a potter's wheel.

TP07-7007 **(Fig. 22–23)**. Rim-wall fragment of a small truncated-cone shaped bowl, with a slightly butt-like rim. The fabric is medium-coarse, with small chaff fibers recognizable on fracture. The sherd is covered by a thick reddish brown slip (5YR 4/4 on the exterior, 5YR 5/4 on the interior) and painted on both surfaces with vertical composite bands (dark gray, 5YR 4/1). No rotation marks are visible, but the vessel was highly polished, retaining coarse, sub-horizontal polishing streaks on both surfaces.

TP07-7006 **(Fig. 24–25)**. Rim and wall fragment of large sturdy bowl or basin, with a rounded rim and a slightly restricted mouth. At the touch, the upper inflection point, below the rim, the sherd is distinctively thicker. The fabric is coarse, with large chaff particles visible in fracture. The core is slightly reduced. Covered by a reddish brown slip (5YR 5/4), it was painted with very dark gray (5YR 3/1) oblique lines. The surface shows, both inside and outside, regular series of horizontal polishing marks.

TP07-7007, in the XR image **(Fig. 23)** shows an abundant component of chaff-temper, well com-

parable to what observed in TP07-7021. The plate reveals a three-layered microstructure, possibly corresponding to 3 horizontal coils or, more likely, to 3 large slabs (the upper one, forming the rim, being much thicker). The orientation of the chaff particles is chaotic, but in the uppermost and thicker slab many vegetal inclusions seem to be parallel and oblique, suggesting some form of rotation. As these voids would run to the upper left, such rotation should have been in an anti-clockwise direction.

The XR plate of TP07-7006 **(Fig. 25)** also shows the abundance of vegetal temper. The microstructure is quite discontinuous, and in general definitely more compatible with SSC than with coil building. The only parallel oblique pores might appear as voids running just below the edge, confirming that the rim might have been regularized on a potter's wheel or perhaps simply fashioned by rotating the fingers along the mouth. The orientation of the voids is the same as for the previous piece; if the vessel rotated on the wheel, the direction was anti-clockwise, but if the oblique pores were simply fashioned by hand, it was the potter's hand moving clockwise.

The two sherds from TP07-7004 **(Figs. 26; 28)** are quite different. They belong to thin-walled, well fired hemispherical bowls with butt-like rims. The paste is very fine, with no vegetal particle on surface or on fracture. Both the surfaces are slipped (respectively pinkish gray, 5YR 7/2 and pink, 5YR 7/4), finely polished and painted with elaborated designs including well drafted hatched lozenges.

Their XR plates are also quite similar. One of them **(Fig. 27)** has a very homogeneous, fine fabric and shows an unmistakable pattern of parallel oblique pores (created by air gaps and bubbles, not by added vegetal particles). These spiralling voids occupy the upper third part of the vessel and become more intense as one moves towards the rim. The pores run to the upper left of the plate. The lower part is thicker, has fewer voids and in general is less readable. The pores, here, might appear sub-vertical or even oriented in the opposite direction (towards the upper right of the sherd). Although the image is not clear, this might suggest that this bowl had been fashioned with alternating rotation (first, for the lower part, clockwise, then, for the upper wall and rim, anti-clockwise). The last XR plate **(Fig. 28)** is quite similar. The abundant parallel oblique pores run to the upper left part of the sherd (thus suggesting anti-clockwise rotation) and fully confirm fast wheel throwing as a primary forming technique. In the lower part of the sherd (but without neat gaps) the orientation of the pores is sub-vertical but proceeds in the same basic direction.

Fig. 22
Tepe Pardis. Rim and wall fragment of a Black-on-Red slipped truncated-cone shaped bowl from layer TP07-7007, interior and exterior surfaces (photo: Federica Aghadian)

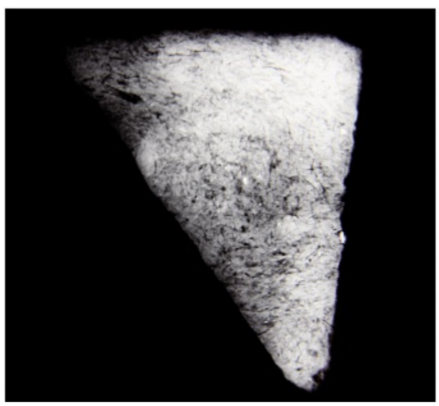
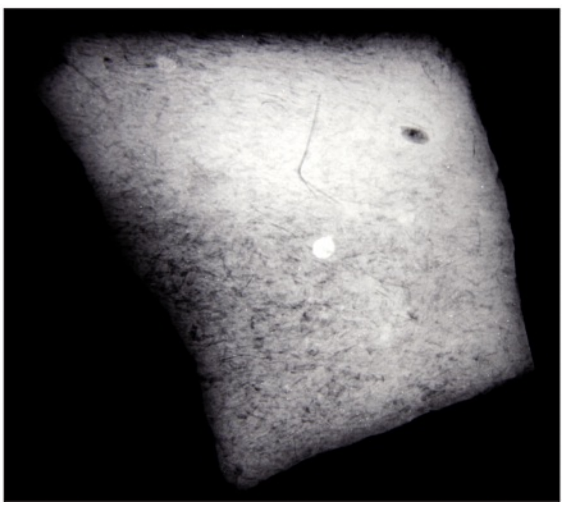


Fig. 23
Tepe Pardis. Mammographic XR image of the microstructure of the sherd in **Fig. 22**. The microstructure, enhanced by the abundant chaff temper, shows a construction process by Sequential Slab Construction, with a possible partial rotation of the rim



◄

Fig. 24
Tepe Pardis. Rim and wall fragment of large sturdy bowl or basin from layer TP07-7006, exterior and interior surfaces (photo: Federica Aghadian)

Fig. 25
Tepe Pardis. Mammographic XR image of the microstructure of the sherd in **Fig. 24**. Enhanced by the chaff temper and by a variable thickness, the microstructure shows a construction process by Sequential Slab Construction or coils, and, again, signs of a possible partial rotation at the mouth

Our interpretation does not match with the conclusions of Roux and Courty[23] who, relying on micro-structural evidence, proposed that actual potter's wheels were not or very scarcely in use in Middle Asia during the 3rd and 2nd millennia BC. On the other hand, the methodology proposed in their paper, although innovative and ground-breaking, does not seem to have been widely adopted by other analysts in the following decade. We believe that our different views are due to the different approaches we are using (macro-structure vs. micro-structure) and would welcome any future occasion of discussion and practical joint collaboration.

Use of pottery forming and surface finishing tools

Potting tools made of potsherds are rather common in several cultural contexts of ancient Eurasia, no matter the absolute chronology, but are rarely published in detail. The discovery in the Tr. VII-TP07 of a series of ceramic polishers or scrapers obtained by recycling pottery sherds **(Fig. 30–31)**, together with the kilns found in the Trench III and IV, seems to confirm the specialized character of this site. A detailed description is reported in **Fig. 30** and **31** and in **Tab. 4**.

The tools were found in layers TP07-7017, TP07-7015 and TP07-7013. All were made by recycling potsherds belonging to vessels painted in black on a bright red slip. 3 fragments certainly came from bowls or pots having a slightly restricted mouth.

The two largest tools (from layers TP07-7017 and TP07-7015, in **Fig. 30,left; 31**) have very visible worn surfaces on the longest sides. In TP07-7017, the relevant edge has a convex section, and its worn surface may be described as irregularly faceted. The wear planes or facets show abrasion micro-streaks running at variable angles, as if the potter freely moved the "scraper", in smoothing-polishing operations, around the vessel (almost cer-

[23] Roux/Courty 1998.

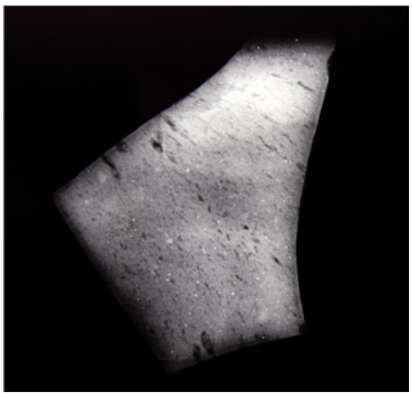


Fig. 26
Tepe Pardis. Black-on-Red painted ware, thin-walled, well fired hemispherical bowl with a butt-like rim from layer TP07-7004 (Chalcolithic), exterior and interior (photo: Federica Aghadian). The fashion is fine and the surface shows abundant rotation marks

Fig. 27
Tepe Pardis. Mammographic XR image of the microstructure of the sherd in **Fig. 26**. The oblique pores demonstrate a construction process on a fast-rotating potter's wheel

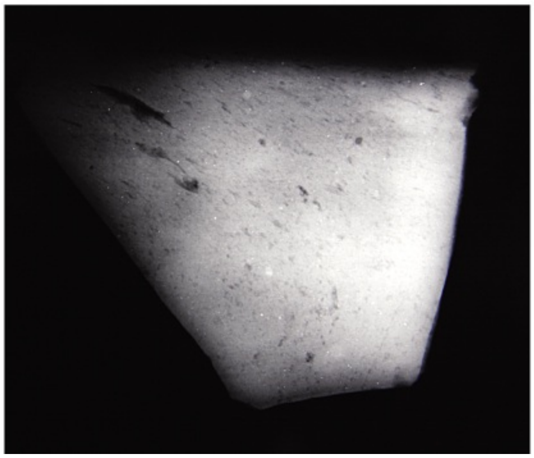


Fig. 28
Tepe Pardis. Black-on-Red painted ware, thin-walled, well fired hemispherical bowl with a butt-like rim from layer TP07-7004 (Chalcolithic), exterior and interior (photo: Federica Aghadian). The sherd is very similar to the specimen of **Fig. 26**

Fig. 29
Tepe Pardis. Mammographic XR image of the microstructure of the sherd in **Fig. 28**. Also in this case the oblique pores demonstrate a construction process on a fast-rotating potter's wheel, particularly evident in the upper part of the bowl's wall

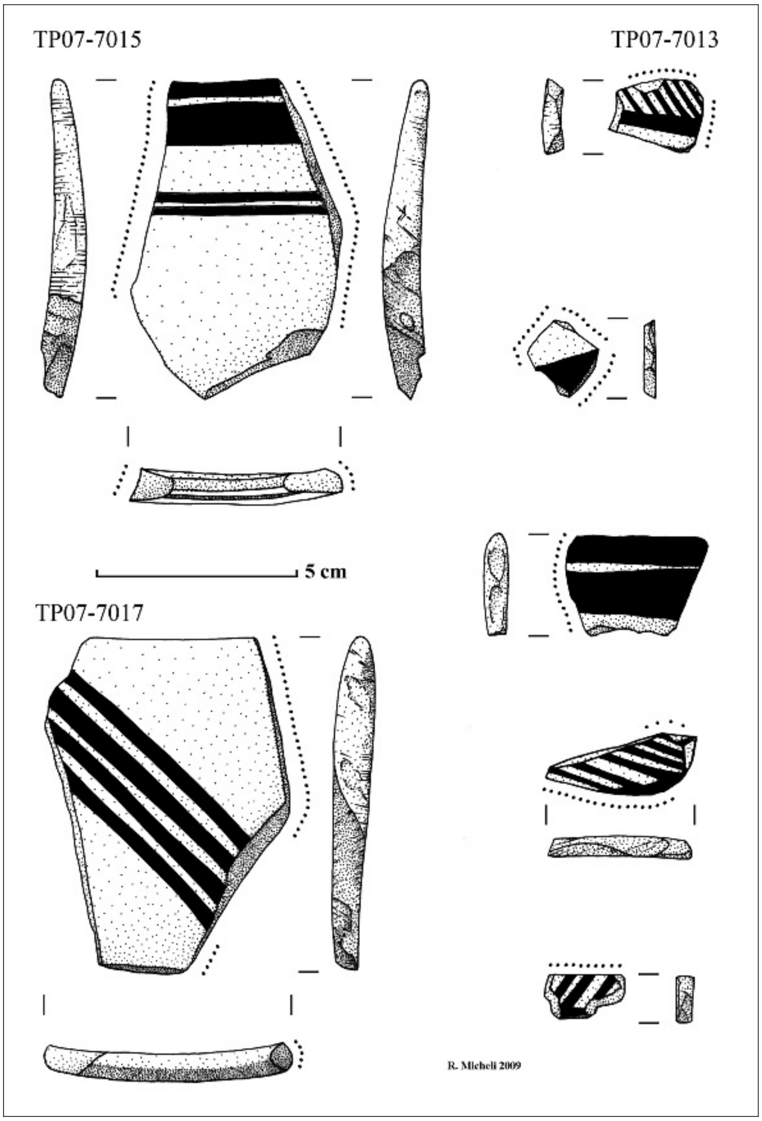


Fig. 30
Tepe Pardis. Drawing of the 6 scrapers or potting tools obtained from modified potsherds found in TP07-VII (drawing by Roberto Micheli). They are fully described in **Tab. 4**

Fig. 31
Tepe Pardis, pictures of the 2 largest potting tools, front and rear (left column in **Fig. 30**) (photo: M. Vidale)

tainly this happened before firing, in a leather-like state of hardness). In the other large tool (TP07-7015), the right side (as defined when looking at the tool with the rim up) shows exactly the same wear pattern. In the opposite edge, the modified fracture edge is flat, the wear is continuous, and shows exclusively regular, horizontal streaks. It is evident that the two sides of the tool were used in 2 different techniques, and this might suggest a high level of skill and specialization. The parallel streaks on a flat fracture surface of the left side are compatible with the use of the tool against a fast-revolving unbaked vessel, most probably for finely polishing its surface, and represent another reliable (even if indirect) indicator for the use of a "fast" potter's wheel in this operation. These tools thus confirm the information provided by the X-rays plates, see above).

Discussion

According to our preliminary results, the 2 main classes here considered (the Late Neolithic Buff Ware and that distinctively associated to the Transitional Chalcolithic) were produced with quite similar materials. The manufacturing areas were probably located in the same sedimentary basin. Grog (from crushed and ground sherds) was occasionally used as a tempering material. The size of chopped chaff particles constantly decreased from the late Neolithic to the Transitional Chalcolithic deposits. While it is a common notion that abundant tempering with chaff – as a fuel-saving technique – allows a faster and safer drying process and more efficient firings, this trend to finer clay mixtures may be also related to the gradual spreading, in time, of the use of the potter's wheel. In fact, fast rotation puts at a disadvantage the tempering of clay with large-sized inclusions.[24]

The first survey of the ceramic forming techniques on record in this test trench of Tepe Pardis shows a somehow surprising range of different pottery forming techniques. Sequential slab construction or SSC seems to have been widely used since the earliest (Late Neolithic) occupation levels. In spite of the problems in distinguishing this approach from coil building, this latter technique might be attested since the beginning (layer TP07-7023) for making large cylindrical chaff-tempered containers. In particular, we are inclined to think that regular butt and dove-tail joins observed in the fracture sections of some fragments (see the examples in **Fig. 15**) is more compatible with coiling rather than with SCC.

Other ceramic forming techniques identified with confidence in the TP07 assemblage are 2-step moulding within baskets and shaping by beating onto convex moulding surfaces, most probably obtained (as ethnographic examples might suggest) from broken or unbroken globular pots.

Ultimately, XR images reveal the use of an efficient, fast rotating potter's wheel since the very beginning of the Transitional Chalcolithic levels. This technique was well known at the time, because the inner structure of TP07-7018 involves the full mastering of a complex set of centering-opening-lifting movements, and not certainly a faltering approach to a newly invented technical device. The implications are manifold.

[24] Sinopoli 1991, 101.

The preliminary study of the assemblage from TP07 actually suggests that SSC, coil-building and fast wheel throwing might have coexisted much longer than expected. There would be no "slow wheel" forming technology to represent a convenient evolutionary ancestor for fast wheel throwing. What many archaeologists, so far, called "slow wheel" might have included a set of different technical approaches, in the first place SSC and coiling followed by a final thinning and fashioning on the potter's wheel. The potter's wheel must have been invented in different regions of South and Middle Asia at least in the last stages of the Neolithic (during the 6th millennium BC) and remained latent for 3 or 4 millennia, until, in the last centuries of the 4th millennium BC, and in the context of the formation of the early city-states, it suddenly became very useful for producing in mass small cheap containers such bowls and beakers.

Although we traditionally see each technical approach to pottery forming as an alternative, it is very probable that, in many instances, the techniques we recognized were combined one with the other. For example, both at Cheshmeh-Ali and Tepe Pardis SSC involved the use of elongated preformed slabs that might have approached the definition of coils, and in some instances these elements were assembled on the potter's wheel, or, anyhow, with fast rotating movements.

The find of a series of ceramic scrapers and/or polishers in Transitional Chalcolithic layers underlines the specialized nature of Tepe Pardis as a ceramic producing centre. The production of a grog temper, the possible use of upturned pots as moulds and the recycling of sherds for making specialized ceramic tools are as many expression of an expedient, resource-optimizing approach to craft production. One of the tools (from layer TP07-7015) was clearly used, on different edges, for 2 different technical tasks. The wear on one of the sides is fully compatible with polishing the surface of a fast rotating vessel. In this latter case, the potter's wheel – from a cognitive viewpoint – was already used as a vertical lathe.

Iron-manganese pigments, possibly extracted from the same geological contexts of the exploited clays, were selected and processed as base materials for painting. Chalcolithic wares, painted and unpainted, were fired, at least to a great extent, in a two-step process, first in strongly reducing atmospheres, then in strongly oxidized conditions. Although part of the products from the lowermost layers in TP07 also seem to have been fired in that way, too, the widespread experimentation of this technique must have been tied to the invention of the sophisticated multiple-chamber firing installations or kilns excavated at Tepe Pardis, whose precise functioning remains to be cleared.

In the considered range of time, painted pottery became more and more popular. Elementary statistics on the variation (across the sequence, in time) of the width of brushstrokes indicate that potters became gradually more competent, as the designs became gradually finer and more complex. In particular, the constant decrease of the minimum width of brush strokes from layer 7020 to 7005 may be taken as a sign of the increasing skill and possibly growing specialization of the painters. In the topmost layers of the TP07 sequence, the same simple statistics show that large lines used for delimiting bands and fields became well distinguished from the thin lines use for hatching and filling the inner spaces: probably, an aspect of the growing standardization of the painted designs.

Conclusions

Although the collection we tested, at present, is still admittedly very limited, the evidence of a fast-wheel forming process at Tepe Pardis ranges among the earliest so far proposed in the Iranian Plateau and across the whole of South and Middle Asia. It suggests that the fast wheel was (at least) a Late Neolithic invention. Further studies are doubtless required (in the first place more X-rays imaging and a careful study of the "slow wheel" found in the dig), but it is clear that in the fifth millennium BC, at Tepe Pardis, an evident progress in the selection and preparation of clays and in the forming processes well matched the invention of the new multi-chambered kilns.

The hypothesis that Chalcolithic wares were fired at higher temperatures than the previous Neolithic vessels is not confirmed by our first analytical results. But while Late Neolithic wares were already fired at temperatures equal or above 850 °C, they are clearly more brittle, porous and soft than the later Transitional Chalcolithic wares. Most probably, thanks to the new kilns and the finer, uniform vegetal temper, Transitional Chalcolithic wares were fired more efficiently, for longer times (see **Fig. 16** and the neo-formed minerals in **Fig. 13**) and in more controlled conditions. In particular, as about 30 % of the Transitional Chalcolithic potsherds show a reduced core, the vessels were first systematically fired in strongly reduced conditions, thus lowering the temperature required for a partial syntherization of the clay pastes and the painted designs, and then exposed to strongly oxidized atmospheres, turning the vessels red (but not the partially vitrified pigment, that remained black).

Tepe Pardis appeared in our trenches as a specialized pottery producing village. In the current evolutionary models,[25] it might be viewed as a case of "workshop industry". Such craft organizations would be distinguished by increased scale and efficiency of production by part-time or full-time specialists, often active in small-scale family workshops. There would be a high rate of technical innovation, increasing standardization and substantial improvements in firing technologies, because only thanks to such ameliorations "... pottery is produced more or less year-round, with the exception of rainy seasons".[26]

On the Iranian Plateau as well as in Central Asia, the fifth millennium BC is marked by the appearance of larger, multi-roomed houses, a sign of the emergence of "extended families" as the most important co-residential unit. While new excavations and studies are needed to understand how ceramic production could be organized in the multi-roomed buildings of Tepe Pardis, the possible existence of forms of sex-age specialization and the role of seasonal variations, there is no doubt that such a theoretical model well fits the present archaeological evidence.

Previous models have often emphasized the role of technical innovation in ceramic production as depending upon (or, on the contrary, promoting) political centralization (for example, for the late 4th millennium BC developments in southern Mesopotamia and Susiana: see Nissen, and for discussion and references Pollock).[27] In particular, the traditional notion is that fast wheel throwing and moulding emerged in the second half of the fourth millennium BC in correspondence with the formation of the first early South and Middle Asian states, and with the emergence of new, sharp social hierarchies. The evidence now suggests that the Transitional Chalcolithic potters of Tepe Pardis were familiar with a form of fast potter's wheel, applied incipient forms of moulding and had very advanced firing facilities since at least 5000 BC. Technical progress, in this light, might be seen as one of the variables involved in the growth of social complexity, but hardly as one of its causative factors.

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[26] Sinopoli 1991, 100.
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Summary

A preliminary paleo-technological study of a collection of well-stratified potsherds excavated in the site of Tepe Pardis (Tehran plains, Iran) allowed us to monitor a series of important technological changes in ceramic production from the Late Neolithic through the Transitional Chalcolithic (ca. 5200–4600 BCE). Preliminary tests show that the change from the apparently softer, buff-coloured painted vessels of the Late Neolithic to the distinctively harder red-slipped and black-painted wares of the Transitional Chalcolithic did not involve different raw materials or higher firing temperatures, but probably required longer times of firing and a more efficient and ingenious control of the firing process. This evolution is doubtless related to the invention of the sophisticated four-chambered kilns discovered in rows in this specialized ceramic-producing village, whose functions and technology are still under scrutiny. The pottery, to a great extent, was built with a Sequential Slab Construction process, the most archaic forming technique so far studied in South Asia. However, coil building was also on record for both large and medium-sized containers since the Late Neolithic, and by the end of the Transitional Chalcolithic its use might have spread to other ceramic forms. We also gathered positive evidence of an early use of fast potters' wheels, reflected not only in the structure of some potsherds (as visible by the means of advanced X-rays techniques) but also in a set of specialized potting tools and possibly in the gradual reduction, in time, of the size of the chaff-temper particles added to the clay mixtures. Although apparently wheel-throwing was used only to a very limited extent, the potters of Tepe Pardis had a basic familiarity with this specialized technique and experimented it with clay mixtures of variable texture and possibly with different forms. The co-existence of completely different approaches to the forming of vessels reveals a technological intricacy so far unreported. While conforming to a growing body of ethno-archaeological information, the evidence from Tepe Pardis questions the traditional models on the evolution of ancient ceramic technologies in the early farming communities of Middle Asia. While more research is certainly needed to substantiate our preliminary conclusions, the early evidence of the fast wheel throwing discovered in the Transitional Chalcolithic of Tepe Pardis ranges among the earliest so far detected, and underlines the key role of the early settlements of the Tehran plains in the development of socio-technical complexity across the Iranian plateau.

تکامل تکنولوژی ساخت سفال در دوره نوسنگی و انتقالی کالکولیتیک در تپه پردیس، ایران

کلید واژه: نوسنگی، مس-سنگ، سفال، کوره، چرخ سفالگری، تپه پردیس، تکنولوژی، سفال نوع چشمه علی، سیلک I

از نیمه دوم هزاره ششم و اوایل هزاره پنجم قبل از میلاد در صنعت سفالگری ساکنان فلات مرکزی ایران تغییرات بسیار زیادی صورت گرفت که مهمترین آن تولید سفالهای قرمز رنگ منقوش و بسیار ظریفی است که بنام سفالهای نوع سیلک II و نوع چشمه علی آنرا می شناسیم. لازم به ذکر است که تولید این نوع سفال تقریبا از 5200 قبل از میلاد در بسیاری از نقاط فلات مرکزی رواج پیدا کرد و حال آنکه قبل از آن سفالهایی تولید می شدند که از لحاظ سبک و تکنولوژی ساخت بسیار متفاوت بوده اند. یکی از مهمترین انواع آن سفالهای نوع نخودی منقوش سیلک I را می توان نام برد که در محوطه های پیش از تاریخ دشتهای تهران، سیلک و قزوین بدست آمده که تولید آن در حدود 5200 قبل از میلاد منسوخ گشت. اینکه تغییر رنگ سفال (از نخودی به قرمز) ناشی از استفاده از منابع گل خام جدید بوده و یا اینکه در نتیجه تغییرات تکنولوژیکی سفالهای قرمز منقوش تولید شده اند پاسخ روشنی قبل از پژوهش حاضر به آن داده نشده بود. پرسش دیگری که در این ارتباط مطرح بوده این است که نوع کوره هایی که برای پخت سفالهای نوع سیلک I و سیلک II استفاده می شده از چه نوعی بوده اند و سفالها در چه دمایی حرارت دیده بودند. سومین پرسش مهم دیگر اینکه در چه زمانی بشر از چرخ سفالگری برای تولید سفال استفاده کرده بود؟ بی شک استفاده از کوره های سفالگری پیشرفته و تولید انبوه سفال بوسیله چرخ سفالگری یکی از مهمترین تحولات اقتصادی و تکنولوژیکی بشر پیش از تاریخ بحساب می آید که باستان شناسان از آن بعنوان تکنولوژی پیشگام در قبل از استفاده از کوره های فلز نام برده اند. تپه پردیس از محوطه های مهم پیش از تاریخ می باشد که در نزدیکی شهر قرچک ورامین قرار گرفته و در طی سه فصل مورد کاوش گرفت. دوره پیش از تاریخ تپه در برگیرنده آثاری از اواخر هزاره ششم، پنجم و چهارم قبل از میلاد می باشد. کاوشهای صورت گرفته در بخش پیش از تاریخ در برگیرنده کارگاههای سفالگری است که محدوده ای حدود 1600 متر مربع را در بر می گیرد. در این قسمت نه تنها کوره های سفالگری کشف گردید بلکه شواهد مستقیمی از ادوات و ابزارهای مربوط به سفالگری بدست آمده است (برای اطلاع بیشتر رجوع شود به مقاله Fazeli et al 2007). پژوهش حاضر سعی نموده تا با استفاده از داده های باستان شناختی و مطالعه شیمیایی و فیزیکی خاک سفالها و استفاده از تکنیک رادیو گرفی سیر تطور سفالگری را از هزاره ششم تا اوایل هزاره پنجم را مورد مطالعه قرار داده و به پرسش های مورد اشاره پاسخ دهد. نتایج مطالعات حاضر سهم مهمی در بازشناخت سازمان تولید سفال در دوره پیش از تاریخ فلات مرکزی خواهد داشت.